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Seasonal incidence and comparative efficacy of insecticides against leafhopper (*Amrasca biguttula biguttula*) and Whitefly (*Bemisia tabaci*) on okra (*Abelmoschus esculentus*)

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ABSTRACT

The field study was carried out during the rainy (*kharif)* seasons of 2019 and 2020 at Sam Higginbottom University of Technology and Sciences, Prayagraj, Uttar Pradesh to investigate the seasonal incidence of whitefly (*Bemisia tabaci)* and leafhopper (*Amrasca biguttula biguttula)* on okra [*Abelmoschus esculentus* (L.) Moench] and evaluated the effectiveness of various insecticides. The experiment was laid out in a completely randomized block design (CRBD) in three replications having following treatments, viz. T_1, Buprofezin 25% EC @0.6 ml/L; T_2, Thiamethoxam 25% WG @0.3 ml/L, T_3, Imidacloprid 17.8% SL @0.2 ml/L, T_4, Triazophos 40 EC @1 ml/L, T_5 Quinalphos 25 EC @2 ml/L; T_6, Acetamiprid 20% SP @0.5 ml/L; T_7, Fenpropathrin 30% EC @0.4 ml/L; T_8, Untreated control. For both experiments, the Arka Anamika variety of okra was used. Whitefly populations peaked at 17.26/plant in early October, while leafhopper populations reached 18.06/plant in late September. Correlation analysis revealed a significant negative relationship between pest populations and mean temperature, particularly for whiteflies (r = -0.68 in 2019 and r = -0.60* in 2020 for the current week, with stronger correlations observed with 1 and 2-week lags). Leafhopper populations exhibited a significant negative relationship with temperature (r = -0.66* in 2019) and a positive association with relative humidity (r = 0.67 in 2020). Linear regression models indicated that temperature accounted for 52.35% and 58.7% of whitefly population variability and 50.24% and 48.82% for leafhoppers in 2019 and 2020, respectively. Among the insecticides tested, acetamiprid effectively reduced whitefly populations by 81.80%, while buprofezin reduced leafhopper populations by 85.63%. Imidacloprid demonstrated the highest cost-benefit ratio, with yields of 115.35 q/ha in 2019 and 113.25 q/ha in 2020.

Keywords: Correlation, *Kharif*, Okra, Regression, Weather factors

Okra [*Abelmoschus esculentus* (L.) Moench], a vital vegetable in the Malvaceae family, is rich in nutrients and widely cultivated in tropical and subtropical regions. India dominates global okra production, contributing over 72% (6 million tonnes) from 0.5 million hectares (NHB 2020), with the state Uttar Pradesh accounting 5.23% (NHB 2020). However, okra cultivation is increasingly challenged by pests and diseases, exacerbated by environmental changes, posing a threat to food security. In India, 72 insect pest species have been documented on okra, with yield losses of up to 48.97% (Sabyasachi *et al.* 2013). Among them, the sucking pest complex, including aphids, leafhoppers, and thrips can cause 54.04% yield losses if not controlled early. The leafhopper *Amrasca biguttula biguttula* is particularly destructive, affecting plants from the seedling stage to fruit setting, leading to yield losses of 50–63.41% by sap-sucking, leaf curling and desiccation (Al-Hamdany and Al-Karboli 2017).

Another major pest is the whitefly *Bemisia tabaci*, which damages plants by sap-sucking and honeydew secretion while also transmits viruses like the yellow vein mosaic virus and okra leaf curl virus, causing up to 80.2% yield loss (Rehmana *et al.* 2015). These pests severely impact plant growth and fruit quality, further threatening productivity.

Effective pest management in okra hinges on understanding pest population dynamics in relation to weather conditions (Das *et al.* 2008). Environmental factors influence the pest population buildup, making it essential to track major pests like leafhoppers and whiteflies to anticipate outbreaks (Prasannakumar and Chander 2014). This study aims to investigate the succession of primary sap-sucking pests affecting okra concerning weather conditions while also assessing the effectiveness of selected insecticides. The

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findings will be offering insights for developing sustainable, cost-effective pest control approaches to ensure stable okra production and enhance food security.

MATERIALS AND METHODS

Experimental setup: The field study was carried out during the rainy (*kharif*) seasons of 2019 and 2020 at Sam Higginbottom University of Technology and Sciences, Prayagraj (25.270° N, 80.500° E), Uttar Pradesh. Under field conditions, separate plots were designated for each experiment in both years to study the seasonal occurrence and effectiveness of selected insecticides against primary-sucking pests of okra. There were three replications in a completely randomized block design (CRBD). For both experiments, the Arka Anamika variety of okra was used.

Seasonal incidence study: To study the seasonal occurrence of leafhoppers and whiteflies, the okra crop was monitored continuously during the growing season, from seedling emergence to harvest. The plot size was 3 m × 2 m. All recommended agronomic practices, except for insecticide application, were followed to grow the crop. Data on leafhoppers and whiteflies were collected weekly during the morning hours (7:00–9:00 a.m.). Five plants were chosen at random from each plot and tagged to determine the population of these sucking pests. Adult insect populations were quantified by examining five leaves/plant: two from the upper canopy, two from the middle canopy, and one from the lower canopy. The average count/plant was subsequently determined and recorded (Bhatt and Karnatak 2018). Weekly meteorological data was collected from the university meteorological observatory at the Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, Uttar Pradesh. These meteorological parameters were correlated with the insect population.

Effectiveness of selected insecticides on okra whitefly and leafhopper: A field trial was carried out to assess the effectiveness of selected insecticides on whitefly and the leafhopper on okra crop during the vegetative stage. The experimental unit plot size was 3 m × 2 m, 45 cm × 30 cm spacing between plants. The following treatments were included: T_1, Buprofezin 25% EC @0.6 ml/L; T_2, Thiamethoxam 25% WG @0.3 ml/L, T_3, Imidacloprid 17.8% SL @0.2 ml/L, T_4, Triazophos 40 EC @1 ml/L, T_5 Quinalphos 25 EC @2 ml/L; T_6, Acetamiprid 20% SP @0.5 ml/L; T_7, Fenpropathrin 30% EC @0.4 ml/L; T_8, Untreated control. The insecticide treatments (T_1–T_7) were sprayed using a knapsack sprayer fitted with a hollow-cone nozzle. Observations were made on the 3rd, 7th, and 14th days after spraying. Five plants were chosen at random and tagged in each plot and five leaves (two from the upper canopy, two from the middle, and one from the lower portion) were sampled from each tagged plant at weekly intervals. The reduction in the insect populations of the okra whitefly and the leafhopper in comparison to the untreated control (T_8) was calculated by the formula:

$$\text{Per cent reduction over control} = \frac{\text{Number of insects in control} - \text{Number of insects in treatment}}{\text{Number of insects in control}} \times 100$$

Immature and tender fruits were harvested in every alternate day, weighed, and mean yields were calculated for each treatment further, calculating cost benefit ratio of each treatment. Statistical analysis was conducted using R (version 4.1.3). A multivariate regression and correlation analysis were perform to examine the relationship between insect seasonal abundance and climate factors.

RESULTS AND DISCUSSION

Population fluctuation and association with weather factors: The seasonal abundance of primary-sap sucking insects like whiteflies and leafhoppers exhibited a notable relationship with weekly meteorological parameters (Supplementary Table 1). The whitefly population displayed considerable fluctuations, ranging from 0–17.26 individuals

Table 1 Correlation co-efficient between insect pests and different weather parameters during 2019 and 2020

Year	Pest	Time period	Weather parameters		
			Mean temperature (°C)	Mean RH (%)	Mean rainfall (mm)
2019	Whitefly	Current week	-0.680**	0.142	-0.262
		1-Lag week	-0.752**	0.146	-0.258
		2-Lag week	-0.760**	0.165	-0.226
	Leafhopper	Current week	-0.657*	0.056	-0.311
		1-Lag week	-0.723**	0.061	-0.306
		2-Lag week	-0.711**	0.085	-0.264
2020	Whitefly	Current week	-0.603*	0.595*	-0.531
		1-Lag week	-0.712**	0.595*	-0.561
		2-Lag week	-0.775**	0.599*	-0.573
	Leafhopper	Current week	-0.339	0.668**	-0.351
		1-Lag week	-0.397	0.668*	-0.369
		2-Lag week	-0.392	0.676*	-0.353

ns P>= 0.05; * P<0.05; ** P<0.01; and *** P<0.001.

per plant. Peak whitefly numbers were observed during the first fortnight of October in both 2019 and 2020, coinciding with mean temperatures around 28.94°C and relative humidity levels of 85.43%. Following this peak, the whitefly number steadily declined from the first week of November. These observations corroborate the results of Anitha (2007), who recorded whitefly populations on *kharif* okra crops appearing from the first week of August 2006, with maximum incidence during the fourth week of October at 6.43 whiteflies per 10 leaves. In line with these findings, Bhatt and Karnatak (2018) observed whitefly incidence from the 34th SMW to 43rd SMW. Furthermore, correlation analyses revealed a significant negative association between whitefly abundance and mean temperature during the current week (r = -0.68**) in 2019 (r = -0.60*) and 2020 and 1 lag week (r = -0.75**) in 2019, (r = -0.71**) in 2020, along with 2 lag weeks (r = -0.76**) in 2019 and (r = -0.77**) in 2020) across both study years (Table 1). These results consistent with previous studies by Prasad *et al.* (2008) and Singh *et al.* (2013), which also indicated negative relationship between whitefly populations and temperature and/or rainfall parameters. However, associations with other meteorological factors were determined to be non-significant. The multiple regression model of the whitefly numbers in relation to weather conditions were y = 50.571 - 1.618x_1 + 0.0571x_2 - 0.128x_3 for 2019 and y = -20.273 - 0.713x_1 + 0.645x_2 - 0.205x_3 for 2020 (Table 1). These models indicated that at higher temperatures, the mean number of whiteflies tended to be slightly lower. In 2019, the multilinear regression model revealed temperature and relative humidity together accounted for 46.2% of the variance in whitefly abundance, which was statistically significant (F=4.72, P<0.05). Similarly, when considering all three weather factors, the model explained 52.4% of the variance, though it was not statistically significant. In 2020, the combined effect of mean temperature and relative humidity explained 52.9% of the variance in whitefly abundance, although it was not statistically significant (F=6.18, P<0.05). Furthermore, when all three weather factors were considered together, the model accounted for 58.7% of the variance, also showing statistical significance (F=4.73, P<0.05).

Moving on to the leafhopper population, their incidence reached peaks of 12.20 individuals per plant during the first two weeks of October 2019 and 18.06 individuals per plant during the final week of September 2020, when the temperature was recorded as 28.94°C and 29.25°C respectively. These observations align with previous reports by Yadav *et al.* (2007), who noted leafhopper activity starting from the first week of August and continuing until the third week of September in 2005, whereas in 2006, it occurred from the fourth week of July to the third week of September. Recently, Nalini and Kumar (2018) also documented the occurrence of whiteflies and leafhoppers commencing from the 35th SMW (3rd week of August), gradually increasing, and reaching a peak by the 41st week (2nd week of October). Correlation analyses revealed a significant negative association between leafhopper abundance and mean temperature during the current week (r = -0.66*), 1 lag week (r = -0.72**), and 2 lag weeks (r = -0.71**) in 2019, along with a notable positive correlation with mean relative humidity in the current week (r = 0.67**), 1 lag week (r = 0.67*), and 2 lag week (r = 0.66*) in 2020. Similarly, Natarajan and Sundaram (1997) and Das *et al.* (2003) also documented inverse associations between leafhopper populations and maximum and minimum temperatures, respectively. Corroborating the present study's findings for 2020, Anitha (2007) reported a positive correlation between leafhoppers and maximum relative humidity. Additionally, Chandio *et al.* (2017) stated that evening relative humidity favored leafhopper population development, while Chauhan *et al.* (2023) observed negative correlations between leafhoppers and temperature but positive correlations with morning relative humidity and rainfall. The multiple regression model of the leafhopper population with weather parameters were y = 49.889 - 1.507x_1 + 0.026x_2 - 0.129x_3 for 2019 and y = -67.257 - 0.047x_1 + 0.995x_2 -0.156x_3 for 2020 (Table 1). While higher temperatures were linked to slight decrease in average leafhopper numbers and a tendency for population decline, while in 2020, increased humidity corresponded to higher leafhopper abundance. For leafhoppers in 2019, multiple linear regression models showed a consistent, significant inverse association with temperature, suggesting a potential temperature-dependent response in leafhopper populations. The R^2 values indicating that the models accounted for 11.5%–50.2% of the variance in leafhopper abundance and statistically significant (P<0.05). For 2020, the multilinear regression model revealed that the combined effect of mean temperature and relative humidity showed a significant positive correlation with leafhopper abundance (F = 4.65, P<0.05) (Table 1). The estimated regression models support the correlation results, exhibiting a significant negative effect on whitefly and leafhopper abundance by temperature and a significant positive effect by relative humidity, whereas, rainfall was non-significant (Table 2).

Effect of different insecticide treatments on sucking insect pests of okra: An evaluation of the efficacy of various insecticide treatments against okra pests is presented in (Table 3). The treated plots exhibited a mean whitefly population ranging from 1.44–4.76 individuals per plant. Notably, the T_6 (Acetamiprid) treatment demonstrated the lowest mean whitefly count of 1.44, corresponding to an 81.80% reduction compared to the untreated control. In contrast, the control plot (T_8) harbored a significantly higher whitefly abundance of 7.91 individuals per plant relative else treatments (Table 3). The variations between treatments were statistically significant (F = 109.02, P<0.05). These findings on the efficacy of neonicotinoid insecticides like acetamiprid and imidacloprid are further substantiated by the work of Saha *et al.* (2011), who observed effective whitefly control using neonicotinoids, coupled with advantageous cost-benefit ratios. Reinforcing these results, Zaini (2017) identified acetamiprid 20 SP as a highly promising option for whitefly management. Regarding leafhopper abundance,

Table 2 Model with multiple linear regressions along with coefficients of determination (R^2) regarding the seasonal abundance of sucking insect of okra based on weather parameters.

Name of the insects	Year	Regression model	R^2	$100R^2$	AICc	Press	F statistic
Whitefly	2019	$y = 53.89 - 1.63x_1$	0.46	46.18	5.62	147.17	$F_{(1, 12)} = 10.32$ (P<0.01)
		$y = 53.678 - 1.631x_1 + 0.004x_2$	0.462	46.20	5.76	147.13	$F_{(2, 11)} = 4.72$ (P<0.05)
		$y = 50.571 - 1.618x_1 + 0.0571x_2 - 0.128x_3$	0.524	52.35	5.78	130.30	$F_{(3, 10)} = 3.66$ (P=0.05)
	2020	$y = 47.366 - 1.367x_1$	0.364	36.38	6.17	254.22	$F_{(1, 12)} = 6.86$ (P<0.05)
		$y = -14.967 - 1.0152x_1 + 0.670x_2$	0.529	52.93	6.01	188.09	$F_{(2, 11)} = 6.18$ (P<0.01)
		$y = -20.273 - 0.713x_1 + 0.645x_2 - 0.205x_3$	0.587	58.70	6.02	165.04	$F_{(3, 10)} = 4.73$ (P<0.05)
Leafhopper	2019	$y = 51.654 - 1.541x_1$	0.431	43.12	5.63	149.36	$F_{(1, 12)} = 9.09$ (P<0.01)
		$y = 53.029 - 1.520x_1 -0.027x_2$	0.437	43.69	5.77	147.86	$F_{(2, 11)} = 4.26$ (P<0.05)
		$y = 49.889 - 1.507x_1 + 0.026x_2 - 0.129x_3$	0.502	50.24	5.79	130.66	$F_{(3, 10)} = 3.36$ (P=0.063)
	2020	$y = 31.092 -0.809x_1$	0.115	11.52	6.60	390.68	$F_{(1, 12)} = 1.56$ (P=0.235)
		$y = -63.220 - 0.275x_1 + 1.014x_2$	0.458	45.81	6.25	239.27	$F_{(2, 11)} = 4.65$ (P<0.05)
		$y = -67.257 - 0.047x_1 + 0.995x_2 - 0.156x_3$	0.488	48.82	6.33	225.98	$F_{(3, 10)} = 3.18$ (P=0.071)

x_1, Mean temperature (°C); x_2, Relative humidity (%); x_3, Mean rainfall (mm); y, Insect population.

Table 3 Efficacy of selected insecticides against sucking insect pests of okra (mean of three sprayings)

Treatments	Concentration/ Dose (g/ml)/L	Pooled data of 2019 and 2020			
		Mean no. of Whitefly/plant	% reduction over control	Mean no. of leafhopper/plant	% reduction over control
Buprofezin 25% SC (T_1)	0.6	1.51[de]	80.91	0.95[c]	85.63
Thiamethoxam 25% WG (T_2)	0.3	1.76[de]	77.75	1.21[c]	81.82
Imidacloprid 17.8% SL (T_3)	0.3	1.54[de]	80.53	1.39[bc]	79.03
Triazophos 40 EC (T_4)	1.0	4.76[b]	39.82	3.25[b]	51.02
Quinalphos 25 EC (T_5)	2.0	2.56[c]	67.64	2.56[bc]	61.52
Acetamiprid 20 SP (T_6)	0.5	1.44[e]	81.80	1.83[bc]	72.40
Fenpropathrin 30% EC (T_7)	0.4	2.16[cd]	72.69	1.56[bc]	76.54
Control (T_8)	-	7.91[a]	-	6.64[a]	-
Level of significance		**		**	
CV (%)		10.46		34.86	

Means followed by the same letter(s) in the same column are not significantly different from one another according to Tukey's HSD. ** and * denote significance at 1% and 5% levels of significance, respectively.

the mean number varied from 0.95–3.25 individuals per plant across the treated plots. The treatment T_1 (Buprofezin) proved most effective against leafhoppers, with a mean of 0.95 individuals per plant, resulting in an 85.63% population reduction. These results are consistent with earlier research by Kittiboonya *et al.* (2007), Hasnain *et al.* (2011), and Ramalakshmi *et al.* (2012), who reported the efficacy of buprofezin in controlling leafhoppers and whitefly nymphs.

The economic viability assessment revealed that the Imidacloprid 17.8% SL (T3) treatment produced the highest yields of 115.35 q/ha in 2019 and 113.25 q/ha in 2020, accompanied by favorable cost-benefit ratios of 1:4.28 and 1:4.18, respectively (Supplementary Table 2). Closely following was the Thiamethoxam 25% WG (T_2) treatment, yielding 109.40 q/ha in 2019 and 111.4 q/ha in 2020, with robust cost-benefit ratios of 1:3.98 and 1:4.09. These findings support other studies consistently identifying imidacloprid and thiamethoxam as delivering the highest yields and most favorable economic returns for okra cultivators. Kumar *et al.* (2015) found imidacloprid 17.8 SL to have the highest cost-benefit ratio of 1:8.94, coupled with maximum yields. Likewise, Dabhi and Koshiya (2014) and Gadekar *et al.* (2016) highlighted the superior performance of these neonicotinoid insecticides in terms of both yield and cost-benefit analysis. While treatments like acetamiprid and buprofezin were also found effective in controlling the target pests, the lower yields observed in those plots may have been influenced by unaccounted factors, such as soil fertility or environmental conditions. Nonetheless, the consistent and economically viable results for imidacloprid and thiamethoxam render them highly attractive options for okra growers seeking efficient and profitable pest management solutions.

Finally, the study elucidated the population dynamics of leafhoppers and whiteflies on okra, revealing their peak infestation periods and associations with weather factors like temperature and humidity. Imidacloprid and thiamethoxam were identified as potent and profitable insecticidal solutions, effectively suppressing these pests which are on par with the acetamiprid and buprofezin. These findings provide valuable insights to devise sustainable, cost-efficient pest management strategies, safeguarding okra yields and contributing to food security.

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